RSP-0096

REPORT

Development Of A Regulatory Monitoring Program For Shiftwork Systems At Canadian Nuclear Power Plants

by

Kevin W. Kulp
Circadian Technologies, Inc.

Prepared for

The Atomic Energy Control Board
Ottawa, Canada

September, 1999

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Development of a Regulatory Monitoring Program for Shiftwork Systems at Canadian Nuclear Power Plants

A report prepared by Kevin W. Kulp, Circadian Technologies, Inc., under contract to the Atomic Energy Control Board.

ABSTRACT

This project determined and evaluated international shiftwork regulatory monitoring policies in key industries such as nuclear, transportation, and petrochemical. Regulators in European, Asian, and North American countries were contacted to fill out a survey instrument which explored the extent of safety-related shiftwork monitoring. Responses indicated that the depth of monitoring practices varied substantially by country and industry, and that no specific country monitors all shiftwork-related factors which can contribute to fatigue and safety incidents. Recommendations for a Canadian regulatory shiftwork monitoring program were provided based on "best practices" from the international survey results.

A. Introduction

A.1. Purpose
The purpose of this report was to provide AECB staff with an overview of safety-related shiftwork monitoring practices used by international regulators, so as to help determine best practices in evaluating the AECB's approach to shiftwork monitoring. This report includes a comparison by continent and industry of current international practices. The information gathered is meant to aid the AECB in evaluating their current practices, as well as to provide guidelines for what a best practices shiftwork monitoring policy might entail.

A.2. Scope
The scope of the research project was to identify the aspects of a shiftwork system that impact on safety performance, and to produce a set of recommendations that can be used by the AECB to establish a regulatory monitoring program for shiftwork systems. By integrating such a system into existing regulatory practices, the AECB can develop a best practices system that encompasses the preferred practices of nuclear regulators world-wide.

Project tasks included reviewing international programs/practices and any associated documentation (e.g. guidelines, standards) for regulating shiftwork systems in high reliability organisations. This information was obtained from regulators in the nuclear, petrochemical, transportation and military industries internationally. The review sought to identify the aspects of shiftwork systems that are monitored by regulatory bodies (e.g. shift schedule design, overtime regulations, fitness for duty), the methods for monitoring and the frequency of monitoring activities. The current approaches used by the AECB to monitor shiftwork systems (e.g. performance indicators, scope and timing of reviews, applicable acts and regulations, etc.) were reviewed in conjunction with international data gathering.

Based on the results of the aforementioned activities, recommendations were provided for establishing an AECB shiftwork system monitoring program. The recommended monitoring program encompasses best practices of international regulators, preferred monitoring methods and the preferred monitoring frequency. It also provides recommendations for integrating a regulatory monitoring program for shiftwork systems into existing AECB activities and systems such as databases and event reporting.

A.3 Background
Many industries, including nuclear power plants, operate 24 hours a day, seven days a week, 365 days a year in order to meet demand and maximise productivity. Depending on the industry, this continuous operation might be the result of a need to increase asset utilisation, maximise production, reduce the down time associated with starting up and shutting down a continuous process flow, or to meet the continuous energy demands of the public. Continuous operations require the presence of alert, fit for duty human operators at all hours of the day or night. In order to assure safe operation, plant operation often requires that operators be alert and able to respond to changes in operating parameters at a moment's notice.

Unlike machinery, human physiology is not well suited to the demands of continuous operation. The human biological clock (the Suprachiasmatic Nucleus, or SCN) regulates the body's rate of physical and mental activity based on circadian time of day factors, typically increasing physiological activity, mental acuity and alertness during the daylight hours. In order to provide for ample rest and recuperation, the SCN typically lowers the body's activity levels during the night-time hours in order to assure the body rests and recovers. During this period from midnight to 5 a.m., blood pressure and body temperature drop while melatonin levels in the brain rise, in an attempt by the biological clock to make the person fall asleep. This varying level of alertness affects even workers on straight night shifts, and results in inconsistent levels of performance from humans working during a period of their body's circadian nadir.

Alertness lapses in twenty-four hour operations typically take the form of microsleeps. Microsleep is defined as a very brief, often unexpected episode of sleep that occurs in the middle of ongoing wakeful activity. Microsleeps are common in individuals who are sleep deprived or excessively sleepy. Episodes of as short as several seconds can be identified with the use of electroencephalogram (EEG) monitoring, although it is not uncommon for episodes to last for several minutes or more. Torsvall and Ackerstedt (1986) found microsleeps and sleepiness to play an important role in the occurrence of night-time accidents.

Regulatory shiftwork monitoring in safety-sensitive industries becomes relevant with the understanding that certain shift schedules, staffing levels and schedule rotation patterns can significantly affect the level of employee sleep deprivation and thus the frequency of microsleeps. On schedules which leave employees significantly sleep deprived due to industrial jet lag or insufficient recovery time between blocks of shifts, fatigue levels can be shown to rise and the frequency of microsleeps to increase. Identifying schedule components which are likely to increase fatigue amongst the operators of regulated plants could assist regulators in helping maintain safe and effective operations.

B. Methodology

B.1. Methodology

In order to analyse international regulatory shiftwork monitoring practices, CTI developed a survey in collaboration with the AECB Human Factors Section. This survey (see appendix) was designed to determine the extent, if any, that regulators monitored different facets of shiftwork.

Regulators were contacted in the United States, England, France, Germany, Sweden, Japan, China, and Korea. Targeted industries were nuclear, transportation, military, and petrochemical. Regulators were typically contacted by phone, email, and fax.

The project results have several limitations. Due to restrictive time constraints, not all targeted regulators responded to the survey within the time limits allowed by the project. As a result, data acquisition is uneven across varying industries. The nuclear industry, as expected, had the highest response rate by regulators. In addition, all data gathered is as per the survey respondent; the possibility of incorrect data exists if the survey respondent misinterpreted a portion of the survey.

C. Findings

C.1. International Programs and Practices Review

C.1.1. Literature Review

Schedule Elements

A variety of elements make up any given shift schedule. The interaction of these with the age, experience and preferences of shiftworkers strongly affect the relative fatigue level associated with any given schedule. As noted below, some components carry should more weight than others when evaluating a shift pattern. The primary elements of a shift pattern include:

- Length of the work week
- Number of crews
- Number of consecutive shifts
- Length of shifts
- Days on/days off pattern
- Schedule regularity
- Starting times
- Fixed vs. rotating shifts
- Direction of rotation
- Speed of rotation
- Number of consecutive scheduled rest days
- Frequency of scheduled rest days

In nuclear power plants, operation will occur seven days per week, 24 hours per day, 365 days per year. As a result, it is uncommon to find five day schedules in nuclear operations, barring ancillary, administrative and support functions.

Although four crew systems are most common in traditional industry and some non-nuclear generation plants, five and six crew systems are commonly used in nuclear facilities to provide sufficient time for training. These schedules rotate all operators through a Relief Week where they cover for absences and provide relief for regularly scheduled operators. Six crew systems also provide a Training week once per six weeks, enabling on-site dedicated training. Five and six crew systems typically require more employees than do four crew systems, and thus are correspondingly more expensive to operate.

The number of consecutive shifts an employee will be scheduled to work varies substantially with the length of their work shift and the schedule pattern that they are on. Eight-hour shifts often require five to seven (or more) consecutive shifts worked before providing time off. Due to the longer day worked, 12-hour shifts are rarely scheduled for more than four consecutive days. Exceptions exist, especially in the petrochemical industry, but are not commonly considered safe by shiftwork researchers. A non-nuclear Canadian Power Plant recently found that a schedule which required employees to work five consecutive 12.5 hour night shifts significantly increased fatigue levels, according to a study by Ronald Heslegrave at the University of Toronto (Heslegrave, 1999).

Shift lengths are traditionally eight or twelve hours, with 0 to 30 minute overlap between shifts. Ten hour shifts are seldom used other than training weeks, and six hour shifts are seldom scheduled due to their unpopularity. It should be noted that operations on 8-hour shifts

occasionally require operators to work a "double", or 16 hours; this practice should be strongly discouraged in safety-critical operations.

The pattern of days on and off is a prime component of a schedule's social compatibility. This pattern is less essential for safety, so long as it stays within the boundaries described below. There is almost an infinite amount of schedule patterns, although a core group of eight and twelve hour shifts are often used due to social, physiological, or operational (e.g. overtime) requirements.

The predictability, or degree of change from day-to-day or week-to-week, is a significant factor in a schedule's degree of employee acceptance. This component does not have a significant effect upon safety.

A schedule's starting time plays a major role in plant safety. Preferred starting times lie between 6:00 and 8:00. In a given plant, the appropriate time is a factor of the amount of commuting time required by employees. Smiley and Moray's research (1989) indicated that start times before 7:00 should be avoided. Current industry practice and industrial experience by CTI indicates that this is slightly conservative in geographic locations where employees live close to the plant and have commutes under thirty minutes. Early start times before 6:00 am are often discouraged, because they require employees to travel to and from work at the most dangerous time of day for single-vehicle accidents. Late morning start times are discouraged because the more exposure to the sun an employee receives while driving home, the greater the likelihood that their biological clock will be reset by the morning sunlight, making good quality sleep difficult or impossible upon returning home. Start times at 6:00 am to 6:30 often successfully balance these conflicting factors. This position is supported by researchers such as Baker, Olsen and Morisseau (1994), who found that error commission during night shifts was most severe between the hours of 3:00 am and 6:00 am.

It should be noted that plant management occasionally wishes to implement start times of 11:00, noon/midnight, or 3:00 in order to have exposure to both crews over the course of a traditional 9 – 5 work day. Although this is often more convenient for management, it can have a significantly detrimental effect on the sleep and safety of employees, and should thus be avoided.

Advantages and disadvantages exist for both fixed (static day or night shifts) and rotating (changing between day and night at a set interval) shifts. Eight hour continuous operation shifts must rotate; many 12-hour continuous operation shifts may be fixed, although some schedules still require rotation. Fixed shifts are often preferred by workers who are concerned with health effects of shiftwork, as research (Wilkinson 1992; Folkard 1992) has shown that sickness and health concerns are lessened on fixed shifts. However, they are often more operationally difficult for plant management, due to challenges with seniority, crew imbalance, and perceived favouritism for day crews. Social factors have been found to favour rotating shifts (Folkard, 1992). Management also tends to favour rotation, as all crews are treated equally. It is not uncommon for workers to favour rotating shifts in order to minimise time spent working nights.

Direction of rotation is only relevant in regards to 8-hour shifts. Research shows that shiftworkers adjust almost twice as quickly to forward (or clockwise) rotation of days to

evenings to midnights, than they do to backwards (or counter-clockwise) rotations of days to midnights to evenings. Backwards rotating schedules often leave employees in a constant state of industrial jet lag, continuously fighting circadian dysrhythmia and the associated fatigue and safety risks.

North American research somewhat contradicts the European viewpoint espoused by Smiley and Moray in the area of a schedule pattern's speed of rotation. European shiftwork researchers such as Knauth (1996) maintain that rapid rotation is desirable, as it can rotate a worker through the schedule rapidly enough that the effect of industrial jetlag is minimised. North American shiftwork research contradicts these findings, showing that slowly rotating or fixed schedules provide superior physiological response and that schedules rotating faster than weekly are too fast for adaptation. Cultural differences play a role in this debate as well, making the determination of the "perfect" rotation pattern impossible. In CTI's industrial experience, the faster a shift rotates back and forth between days and nights, the more fatigued employees tend to become if the schedule does not allow for a substantial (10 or more days) adaptation period with no rotation onto the night shift.

Twelve-hour shifts are physiologically feasible because they provide frequent rest days when the muscles rest and recover. A minimum of 48 hours should occur between scheduled blocks of shifts. Schedules which require "double-backs" (working a night shift followed by an evening shift, for instance) should be discouraged.

The frequency with which rest days occur is a factor in shiftwork as well. In general, a shiftworker should be scheduled to work no more than seven 8-hour shifts before receiving a day of rest; a 12-hour shiftworker should be scheduled for no more than four consecutive shifts before being scheduled for a rest day.

Staffing

Understaffing continuous operations is likely the largest contributor to fatigue levels in continuous operations. An understaffed operation typically results in high levels of employee overtime, thus reducing the amount of rest days and contributing to fatigue.

What many managers of continuous operations do not understand is that an appropriate staffing level takes into account historical absentee levels, vacation coverage, anticipated training, and special projects. This number is not static, and can change over time as senior employees are granted additional vacation leave.

In NPP's throughout Canada, licensees are required to have a minimum crew complement present at any given time, as specified in their licensing agreement. Should the number of qualified employees be less than optimal due to turnover or increased coverage demands, licensees do not have the option of not covering these positions. As a result, operators can be called in on days off in order to fill the complement. Safety can be impacted when this overtime interferes with proper rest and recovery.

A reasonable approximation for a given crew (or position) complement can be estimated through the following formula:

$$\frac{\text{(\# of Benefit Days off x Length of Shift x \# of positions x \# of crews)}}{\text{\# of scheduled work hours per year}}$$

For instance, a position on a 5 crew 12-hour shift may require 50 operators on each crew. Each operator has approximately 22 benefit days off per year with holidays and vacation. If the operators are scheduled to work 2184 hours per year, the formula would work as follows:

$$(22 \times 12 \times 50 \times 5) / 2184 = 30.2.$$

In order to provide built-in relief for the 150 operator positions, 30 additional operators (6 on each crew) would be needed to cover for vacations and anticipated absences. Without this built-in relief, operators would be forced to use overtime to cover absences. The degree to which overtime is used often indicates the relative fatigue of operators required to work it.

Relief staffing in continuous operations can typically take one of several forms. Nuclear power plants in North America commonly utilise five or six crew scheduling systems, which ensures available relief coverage and training opportunities. Four crew operations typically either utilise four self-relieving crews, with extra personnel assigned to each crew to cover for vacations and absences, or a separate dedicated relief crew to cover for scheduled vacations and provide relief during training.

Fatigue Factors

The relative risk of an operator suffering from safety-compromising fatigue at any point is dependent upon a variety of factors. It is not possible or desirable to monitor all of these factors. Nevertheless, when incidents occur the following factors can assist in root cause analysis for determining the degree to which fatigue played a role in human error.

- Time of day (phase of circadian rhythm)
- Day of shift
- Consecutive hours on duty
- Consecutive shifts on duty
- Amount of overtime
- Speed or frequency of shift changes
- Circadian profile (morningness or eveningness)
- Duration, Quality, and Hours since last consolidated sleep
- Cumulative sleep deprivation
- Stimulation/monotony of job task
- Stimulation/monotony of job environment
- Content and timing of last meal
- Ingested stimulants or depressants
- Age of shiftworker
- Physical activity levels

The time of day, or phase of the circadian rhythm that an employee is in, is a major factor which can influence the hour in which a fatigue-related event can occur. Fatigue-related incidents are most prone to occur during times of an individuals' circadian nadir.

In addition, research shows a strong day-of-shift and night-of-shift effect in adjusting to a new schedule. The first two nights of a new schedule are typically the most difficult; circadian adaptation begins to occur in the third consecutive night, improving over subsequent nights as the individual becomes accustomed to sleeping during the daytime and maintaining wakefulness during the night. Day of shift and time of day are a more reliable indicator of fatigue than are the number of hours on duty.

Despite this, fatigue increases as more shifts are worked, largely because insufficient daytime sleep over a number of days can result in chronic sleep debt. Accepted limits of four 12-hour shifts are commonly used in both the nuclear industry and other industrial applications, as studies such as Heslegrave's (1999) find performance degradation on the 5th consecutive shift. Overtime levels are closely linked to fatigue in this regard. As employees work overtime as an alternative to receiving planned rest days, less opportunity occurs to restore ongoing sleep debts.

Research shows that certain people are physiologically suited to shiftwork through their degree of morningness and eveningness. People with a high degree of eveningness are often better suited to shiftwork than strong morning types, as they adapt easier to night shifts and their biological clocks tend to be more flexible in changing sleeping patterns.

Nevertheless, the amount and quality of sleep that an individual has obtained is a critical factor in their degree of alertness. Research by Dawson and Reid (1997) demonstrated that college students who had been awake for a full 24 hours had equivalent reaction times and reasoning ability as an individual with a blood-alcohol level of .10 (legally drunk in many countries). The longer an individual goes without sleep (or with reduced sleep), the poorer performance and the greater incidence of microsleeps (Dinges, 1999).

Certain factors help counterbalance reduced sleep, however. The more interesting, dangerous, or opportunistic the job task, the easier it is for most individuals to stay alert. In addition, the degree of stimulation provided by the job setting (lighting levels, sound stimulation, aroma, distraction levels, and interpersonal interaction) influences alertness levels. The content and timing of meals, as well as the ingestion of stimulants or depressants, will promote or reduce sleepiness as well.

Employee age is a more nebulous factor in adaptability to shiftwork. Shiftwork often becomes more challenging as employees age; ergonomic concerns and physiological changes can make night shifts more tiring than they would be for younger workers. Despite this, many experienced shiftworkers have developed effective coping techniques to help reduce fatigue and improve performance. The degree of physical activity is also a factor in fatigue. Early morning exercise has been shown to phase delay the circadian nadir, delaying it several hours from the time of exercise, and muscular activity increases alertness both during and after exercise.

C.1.2. Survey Results

Of the nineteen regulatory agencies contacted, eighteen responded within the project deadline. Of these eighteen, four reported not monitoring shiftwork at all. Response rate, the largest

variable associated with the project, was limited due to the short time window available and the time of year (July/August) in which the project was conducted. As a result, the survey results provide a clear but not exhaustive picture of international regulatory practices.

Countries responding include Canada, China, England, France, Finland, Germany, Japan, Korea, and the United States. Responses were distributed as shown in the accompanying table.

Continent	# of Survey Responses
North America	6
Europe	8
Asia	4

Industry	# of Survey Responses
Nuclear	12
Transportation	3
Petrochemical	2
Military	1

Responses are summarised by continent for ease of comparison.

Overall, North American nuclear regulators appear to monitor overtime levels and staffing complements to a greater extent than do European or Asian regulators, while European and Asian regulators monitored shift lengths to a greater extent. Regulators were divided between monitoring all employees at the NPP's and only the safety-critical operations staff. Several countries report not monitoring schedules, staffing or overtime at all.

Typically, nuclear shiftwork monitoring is implemented by Resident Inspectors at licensee sites. The frequency of monitoring varies dramatically from regulator to regulator; while it is most common for appraisals to be performed quarterly, yearly or every 18 months, two respondents reported monitoring some shiftwork-related issues on a daily basis.

An analysis of shiftwork monitoring by nuclear regulators shows that the majority of regulators do not monitor shiftwork practices in great detail. Regulators tend more towards a reactive approach, in which any problem linked to shiftwork which arises acts a flag for further investigation. One area which is fairly consistently regulated is limits to hours of work. This varies from a low of 8 hours per day maximum and an average work week of 34.5 hours in one country, to a legal maximum of 16 hours worked in 24 hours and an nominal work week of 40 hours in a different nation. In addition, performance (such as human error and incident reports) are closely tracked across the board. Shiftwork limits are also consistently applied during maintenance outages, with limited exceptions. Despite this, one respondent reported that they had observed apparent violations of this policy during maintenance outages, and was revising their policy to address this.

The majority of regulators have conducted past or on-going research, primarily in the areas of both fatigue and 8-hour vs. 12-hour shifts. Much of this research appears to be available for reference from the individual regulators.

Policies varied dramatically in non-nuclear industries. The most stringent regulation occurs in the Transportation Sector. Transportation scheduling is traditionally driven by hours of service regulations, with no set or consistent time windows for work. Due to the public safety concern, rail and air transport are closely monitored in regards to performance measures and hours of service.

Military regulation is less stringent than nuclear or transportation, as the military often has the latitude of selecting and imposing whatever schedules seem appropriate, including straight work shifts with no scheduled days off. While this can result in less-than-ideal scheduling patterns, performance is typically tracked closely (on a daily basis through Master Reports) to assure safety. Military scheduling is typically set by commanding officers, and does not allow the freedom to set shiftwork policies except at high levels.

In comparison, the petrochemical industry is traditionally on consistent schedule patterns that vary little from month to month, and which can be easily changed with labour and management approval. The North American petrochemical industry was virtually unregulated in the area of shiftwork, with any shiftwork policies (such as overtime pay) being set within the boundary of federal, provincial or state laws by individual firms or sites.

North America responses

North American regulators and licensees surveyed consisted of three nuclear regulators, one transportation regulator, and one branch of the military.

North American shiftwork regulation is moderately consistent between respondents in like industries, with nuclear regulators of both Canada and the United States monitoring aspects of shiftwork. Both respondents use annual or semi-annual reviews of key issues such as overtime management and staffing levels, maintaining the capability of rapid reaction by regulators should shiftwork-related problems arise. Specific laws, guidelines and policies set relatively moderate scheduling limits as compared to other respondents. The responses of shiftwork areas monitored are summarised below.

North American Monitoring Components

	Country A, Nuclear	Country A, Nuclear (2 respondents)	Country A, Airlines	Country A, Military	Country B, Nuclear
Limits to hours of work	ANS 3.2; 16 hrs max per 24, 24 hrs max per 48, 72 hrs max per 7 days	ANS 3.2; 16 hrs max per 24, 24 hrs max per 48, 72 hrs max per 7 days	By week, month, year	No	Must comply with regulations (60 hrs/week)
Shift pattern	Must have 8 hrs min off between shifts	Must have 8 hrs min off between shifts	Some requirements for days off	No	72 hrs off after 3 or more night shifts
Work organisation	As specified by DOE Order 5480.23	No	Computerised scheduling	No	Monitored when an unusual, infrequently performed activity is planned
Tracking and reporting hours of work	As specified by DOE Order 231.1	-	Required to keep records	No	No. Licensees must report violations of 60-hrs/week limit to government
Distribution of Overtime	As specified by DOE Order 231.1	Yes	N/A	No	No
Time or frequency of Shift Turnovers	As specified by DOE Order 231.1	-	Schedules vary week to week	No	Reviewed for new or modified schedules
Transition between shift schedules when changing patterns	As specified by DOE Order 231.1	-	Keep pilots on reserve for emergencies	No	Monitored for significant changes
Performance	Perform root cause analysis; as per DOE Order 232.1a	Yes	Pilots required to report incidents	No	Yes; monitor performance indicator data
General shiftwork related policies	No; napping not permitted	No	Regulations require rest; contractual arrangements cover details	No	Review policies and procedures for hours of work and overtime
Shiftwork during maintenance outages	Scheduling limitations not suspended for outages	Yes	N/A	No	Guidelines not commonly suspended for outages; no structured monitoring

Shiftwork regulation clearly varies by industry and regulator, with several shiftwork-related factors appraised on an annual, semi-annual, semi-regular or ad hoc basis.

Primarily, the North American regulators who were surveyed monitor limits to hours of work by day and by week, minimum time off between shifts, overtime levels, performance and errors, and shiftwork during maintenance outages. North American NPPs make substantial use of 12-hour shifts, with a trend towards conversion to 12's in plants currently on 8-hour shifts.

Responses indicated that North American nuclear plants typically have limited latitude to self-select a new shift pattern or change shift policies without regulator approval, as long as the new schedule falls within legal guidelines. One nuclear respondent indicated the use of both 8 and 12-hour schedules in individual plants, while the other respondent has moved entirely to 12-hour shift systems.

The transportation organisation surveyed has working patterns dictated by scheduling needs and seniority systems, combined with hours-of-duty limitations. The military organisation surveyed utilises a variety of schedules as needed for each specific operation.

The North American research community is active in pursuing research on fatigue, performance and human factors. Much of this research has focused on the feasibility of 12-hour shifts in safety-critical industries. In addition, the transportation regulators are currently involved with extensive research on proper limits for hours of duty.

European Responses

European regulators surveyed included three nuclear regulators, one nuclear licensee and two transportation regulators. Two additional nuclear regulators were unable to respond to the survey within the project deadline.

European shiftwork has substantial cultural differences when compared to North America or Asia. There is a focus on fewer hours per week, more mandatory vacation time, and in some occupations shorter shift lengths. A greater percentage of European shift schedules are of the "Continental", or fast-rotating, variety.

European regulators varied substantially in their approach to monitoring safety. While one nuclear regulator reported that they did not monitor any aspect of shiftwork in relation to nuclear safety, a different regulator and a licensee reported daily checks by Resident Inspectors. The degree of proactive inspection on the part of the Regulators varied significantly from country to country; regulators commonly reported monitoring limits to hours of work, performance measurements, shiftwork-related policies (such as the timing of meetings or shift changes), and shiftwork during maintenance outages. Although tracked by several countries, overtime levels were not closely tracked.

European Policy in setting individual plant shift schedules appears be somewhat more conservative than in North America. One regulator restricts licensees from scheduling safety-critical operations, such as planned shutdowns, from occurring on any shift but the morning shift. In addition, the European Working Time Agreement restricts the use of 12-hour shifts, limiting

somewhat a licensee's ability to set shiftwork schedules. Within this framework, licensees have the ability to set policy so long as safety is not impaired or their licensing agreement violated.

With one exception, European respondents reported conducting moderate shiftwork research. One respondent reported ongoing research projects related to shiftwork and fatigue.

European Monitoring Components

	Country B, Nuclear	Country C, Nuclear	Country D, Nuclear	Country E, Nuclear	Country B, Transport	Country B, Transport (2 respondents)
Limits to hours of work	No	Yes	8 hrs, 34.5 hr week, 170 days/yr on avg.	Legally regulated work hours, OT and vacation	No	Yes
Shift pattern	No	Yes	Yes	Agreed upon within trade unions and employer organisations	No	Yes
Work organisation	No	No	Yes; safety-critical work done in morning	As above	No	Yes
Tracking and reporting hours of work	No	Yes	No	As above	Yes	Yes
Distribution of Overtime	No	Yes	Tracked but not monitored	As above	No	No
Time or frequency of Shift Turnovers	No	Yes	No; others monitor OT. Turnover monitored occasionally	As above	No	Yes
Transition between shift schedules when changing patterns	No	No	No	As above	No	Yes
Performance	No	Yes	Yes (8-10 events/year)	Yes	Yes	No
General shiftwork related policies	No	Yes	Monitor meetings, occasionally patterns	Agreed upon within trade unions and employer organisations	Yes	No
Shiftwork during maintenance outages	No	Yes	Yes, but different procedures	Normal guidelines not suspended	Yes	No

Asian Responses

Three Asian nuclear regulators and one licensee responded to the survey. Regulatory oversight in Asia varies greatly from country to country, as it does in Europe. With one country that reports no monitoring of shiftwork at all, one country that monitors performance and work hours only, and one country that closely monitors a variety of shiftwork-related factors, regulatory policies vary substantially.

The two factors commonly monitored by nuclear regulators were limits to the hours of work and performance measures. One Asian respondent monitors in detail a variety of factors, including shift patterns, work organisation, tracking hours of work, shift turnovers, shift schedule transitions, shiftwork-related policies, and shiftwork during maintenance outages.

One respondent uses Resident Inspectors to periodically (quarterly, annually or infrequently) monitor shiftwork and performance issues for the operations group and crews working shiftwork in the field. Another respondent also reported using resident inspectors to monitor shiftwork, for all groups, on a daily basis.

Overall, comparatively little research on shiftwork by the nuclear regulators was reported. Where research was reported, it centred around studies for optimum shiftwork and maximising performance.

Other than one country's limit of a scheduled 8-hour work day, countries allowed individual NPPs to set schedule patterns within the limit of the law. One regulator reported providing NPPs with advice or direction when shift patterns caused problems.

Asian Monitoring Components

	Country F, Nuclear	Country G, Nuclear	Country H, Nuclear
Limits to hours of work	(8 hrs/day max)	Yes	No
Shift pattern	No	Yes	No
Work organisation	No	Yes	No
Tracking and reporting hours of work	No	Yes	No
Distribution of Overtime	No	Yes	No
Time or frequency of Shift Turnovers	No	Yes	No
Transition between shift schedules when changing patterns	No	Yes	No
Performance	Yes	Yes	No
General shiftwork related policies	No	Yes	No
Shiftwork during maintenance outages	No (other than manning level requirements)	Yes	No

C.2. Current AECB Approach to Shiftwork Regulation

The Canadian AECB currently monitors or regulates a number of shiftwork issues. These tasks are divided between Project Office activities and Human Factors Section activities in Ottawa. Shiftwork monitoring is currently reviewed on an irregular basis. A non-prescriptive approach is used, reviewing the efficacy of different licensee policies without dictating what those policies should necessarily be.

Project Offices are responsible for confirming minimum staffing levels, reviewing shift logs, checking operating parameters, examining event reports, and confirming that the licensee follows regulations and associated legal requirements. The degree of monitoring by Project Officers varying between licensees. In some operations, Project Officers periodically conduct inspections on the night shift; in others, this is done on the day shift.

The Human Factors Section of the AECB (based in Ottawa) currently reviews shift schedules submitted by nuclear power plants when considering a change, reviews policies, practices, and procedures linked to shiftwork, and conducts research on shiftwork. One audit of hours of work during a maintenance outage has been conducted.

C.3. Recommendations

The first step in designing and updating a Canadian AECB Shiftwork Regulatory Monitoring program is determining the extent of such a program's scope. Obviously, at its most detail-oriented end such a program could monitor and regulate the specific schedule types, the change-over times, the schedule for work activities, and so forth.

An ideal system will establish a best practices approach, monitoring the "best" features monitored by regulators internationally, and discarding inappropriate or outdated practices.

There are dozens of aspects of shiftwork which could be monitored by nuclear regulators; that does not mean that all aspects of shiftwork should be monitored or regulated. Safety-critical aspects of operation are fundamentally more valuable for tracking purposes than are shiftwork components which have little or no effect on fatigue and safety.

The following are aspects of shiftwork which have a greater or lesser correlation with fatigue and safety. It is essential to note that where inspection by Resident Inspectors (Project Officers in the Canadian nuclear regulatory context) is indicated, night shift inspection is perhaps more valuable than day shift inspection; due to the limitations of human physiology, fatigue plays a larger role in night shift errors and incidents. Currently inspection during the night shift is not a routine component of the AECB inspection program, and as a result Project Officers rarely have the opportunity to observe operations during early morning hours.

Shift complement (around the clock)

This aspect is currently being monitored by the AECB, as well as most other nuclear regulators world-wide. Ensuring that an operation has an appropriate complement of qualified employees, as specified in the licensing agreement, is essential to safe operation. This should be monitored through licensee reports, combined with periodic spot checks on-site.

In an ideal best practices monitoring system, regulators would continue to rely primarily on licensee reporting for awareness of insufficient shift complement. In addition, periodic unannounced inspection three to four times a year, both during the day and night shifts, will help confirm compliance.

Limits to hours of work

This aspect is currently being monitored by the AECB through standard reporting, and is a relatively common component of monitoring programs world-wide. Examining violations of hours-of-work limits should continue. Due to the potential volume of associated data, it is not recommended that the AECB track hours of work itself, but instead rely on the individual licensees for this data.

Work organisation

Only two respondents reported tracking work organisation (i.e. when safety-critical work is performed within a shift) as part of a regulatory monitoring program. This level of detail is often best left up to individual NPPs, who can decide the most appropriate timing of work to meet safety and operational goals.

One respondent limits safety-critical work to the morning shift. This conservative restriction is a "best practice", but is not required by the majority of regulators; a less restrictive but still sound policy would be attempting to limit safety-critical work between the hours of 1 am and 6 am. It is worth noting that on a rapidly rotating shift schedule, reserving safety-critical work to the morning shift does not ameliorate the effects of fatigue from circadian dysrhythmia.

Distribution and total amount of overtime

Excessive overtime is often considered to be the greatest non-schedule-related source of fatigue in continuous operations. Even if a facility is maintaining a minimum shift complement, working employees a disproportionate amount of overtime quickly eliminates or reduces the quantity of "recovery days" available to employees to rest and recover. Licensee staffing levels should take into account proper relief for vacations, absences, training, and special projects.

Overtime levels are inconsistently tracked by survey respondents, with approximately half of regulators monitoring overtime levels. Due to the potential impact on employee fatigue and safety from an understaffed operation that fills positions through overtime, a best practices approach indicates that overtime levels be monitored for abuses. It is recommended that

overtime levels and distribution be periodically monitored to assure that overtime is equitably distributed and not excessive.

Time or frequency of shift turnovers

While not commonly monitored, the time of shift turnovers can have a substantial effect on employee alertness and performance. The ideal time for shift turnovers varies between 6:00 am and 8:00 am for 12-hour shifts, with the day shift starting in this same range for 8-hour shifts.

The rationale for this changeover window is based on circadian physiology. Changeover times before 6 am require day shift employees to rise excessively early, often curtailing sleep duration, while requiring night shift employees to drive home at the most dangerous time of day. Changeover times after 8 am result in night shift employees' biological clocks having "reset" onto a daytime pattern due to light exposure, thus making daytime sleep significantly more disrupted. As a result, start times outside of this window should be avoided.

In a best practices approach, annual monitoring of NPP start times would help ensure that start times were properly managed.

Shift pattern

The majority of regulators do not monitor shift patterns so long as they stay within the legal constraints of each regulator's country (i.e. whether or not 12-hour shifts are legal, etc.) There is some logic in this; experience shows that the most effective pattern for a site is the one selected by the employees at that site, so long as the pattern is not inherently unsafe. Nevertheless, schedule changes can inadvertently insert fatigue and safety concerns into an otherwise safe operation.

A best practices solution which keeps to a minimum excessive reporting would be for licensees to submit schedules to the AECB for an initial review, followed by an additional review of any substantial proposed change, such as a change in a schedule's length of shift, direction or speed of rotation, or pattern of days on and days off. Reviewing schedules only upon changes reduces the burden of periodic reviews of an operation where nothing substantive has changed. Schedules which are found to contain unsafe elements should be brought to the licensee's attention for review or revision.

In addition, educating licensees as to the subtleties and physiological components of shift schedule design will help ensure that any proposed schedule change will not be unsafe or inappropriate out of ignorance of schedule design techniques.

Transition between schedules when changing patterns

This occurrence is infrequently monitored by regulators, and is a relatively infrequent event. Nevertheless, when transitions such as from 8-hour to 12-hour shifts are made, safety exposure can increase due to communications and fatigue issues. As part of best practices, any such

transition should be monitored to assure that no abuses occur in staffing, violations of limits to hours of work, or in excessive overtime.

Performance

Performance monitoring is a mainstay of most regulators. Human error, number of significant events, trending, and root cause analysis is a common and useful tool of regulators to help determine patterns of safety issues before they result in greater issues. Performance and human error can be tracked in many ways, with greater or lesser detail paid to cause analysis.

The majority of AECB performance data is currently derived from the reportable events due to license violations detailed in regulatory document R-99. One of these, maintaining minimum shift complement, is shiftwork-related. Due to the nature of the different licensees, there is a reported lack of consistency between how different licensees report. Without a consistent and detailed set of internal standards in the AECB for translating each licensee's error codes into the internal standard for the AECB database, it is possible for levels of detail to be lost during the process.

As a result, AECB data analysis and trending of licensee performance and significant event analysis relies on AECB personnel accurately and consistently translating the licensee-reported error codes into a standard format. The AECB is unable to require one utility's reporting system to drive that of other utilities, making this system necessary. This establishes a need for a robust, consistent and detailed internal standard of error code reporting within the AECB. One review of root cause and corrective actions found that approximately 50% of cases credited the symptom of the problem, rather than the problem itself.

In addition, performance indicators such as accident severity rates are not currently tracked or trended by time of day, day of shift, etc. This data can give the AECB valuable insight into the degree to which human error is or could be fatigue related.

As part of a best practices, it is recommended that the AECB continue to refine and implement consistent internal standards for error code reporting. Doing so will result in better access and consistency to performance data. More immediately, trending by time of day can be tracked to look for trends.

General shiftwork-related policies

On a macro level, it is quite possible for a nuclear power plant to have a safe and biocompatible schedule, and yet run employees into the ground by requiring too much overtime. As a result, a best practices standard dictates that reviewing overtime, hours of work policies, and start times is an appropriate action for regulators. Not many regulators reported monitoring shiftwork-related policies, even though this can be integral to maintaining a safe and effective shiftwork schedule.

Not all shiftwork policies need to be monitored by regulators. As an example, policies such as the preferred timing of shift meetings have a lesser bearing on safety, and is a level of detail best determined on an operational level by plant management.

Shiftwork during maintenance outages

Maintenance outages are often a controversial subject. Since plant downtime is best kept to a minimum, many operations would prefer to work employees a substantial number of days in a row without time off. Plants are often under significant pressure to be back up and running as quickly as possible, which sometimes leads to excessive overtime. In some operations world-wide, shift patterns change substantially during these periods, possibly resulting in excessive fatigue.

A best practices approach dictates that any limits to hours of work already in place be maintained during maintenance outages, with overtime levels monitored for potential abuse. This helps maintain alertness and performance without compromising safety. It is recommended that the regulator perform periodic spot checks during the outage to confirm that limits are maintained.

C.4 Follow-Up

This project generated a number of follow-up recommendations for the AECB. Not all positive changes can, or should, be implemented immediately. Recommendations for integrating a shift work monitoring program into existing AECB activities are detailed below.

Gather additional information

While overall response to the survey was good, additional information can be gathered from non-responding regulators to confirm best practices. In addition, individual respondents' policies should be looked into in greater detail where they can help shed light on how that regulator accomplishes best practice tasks.

Clarify basis for monitoring shiftwork

The AECB should clarify from a legal standpoint the extent of its mandate to monitor shiftwork. Clearly, shiftwork is closely tied to a number of safety criteria, but there is a lack of internal consensus as to the extent that monitoring of shiftwork that can be performed by the AECB. Clarifying this will provide a basis for proceeding in establishing a shiftwork monitoring program. For instance, it appears that licensees are not required to submit schedules for review by the AECB, although many choose to do so. A legal interpretation in this area would assist in establishing the scope of a monitoring program.

Investigate international research

Various regulators reported having conducted research on shiftwork and fatigue. It is recommended that where possible, this information be examined and integrated into the AECB's current shiftwork knowledge.

Provide more guidance to licensees

The AECB's non-prescriptive approach limits involvement with licensees' specific policies. However, it is recommended that licensees be educated in both the basics of biocompatible shift design, and methods for determining proper staffing levels.

By sharing this information, the AECB can ease its burden without violating its non-prescriptive approach. Educating licensees in the basics of biocompatible scheduling, the effects of rotation, and what constitutes a safe schedule does not then dictate that the licensee must adopt a specific schedule. However, it gives the individual plants the tools to better design their shiftwork policies within boundaries that they know the AECB considers acceptable.

Likewise, giving individual plants the tools for evaluating a fully staffed crew as opposed to an understaffed operation will help reduce excessive overtime, as well as potentially preventing abuses in manning levels.

Such education should be voluntary, and available as required to licensees. Alternatively, making available internal documents on shift schedule construction would similarly fulfil the need for more information in this area.

Integrate human factors and fatigue education into Project Officers' knowledge base

In order for Project Officers to fully adjudicate fatigue-related safety issues, a consistent grounding in human factors and fatigue should be possessed by on-site AECB staff. In order to enhance knowledge distribution across the organisation, the need for ongoing education in these issues should be addressed.

Conduct periodic night-time inspections

Experience shows that Control Room operations can differ dramatically between day and night. While several Project Officers interviewed saw a benefit to night time inspection, it is not currently part of the routine inspection program, and thus occurs only on an ad hoc basis at present. Quarterly night time inspections would assist in identifying fatigue risks that are not apparent during day shifts.

Refine internal standards for error code reporting

The PRED evaluation managers should continue address the issue of event reporting methods and codes by establishing strong, consistent internal standards for error codes reporting. The benefits of a more robust error code utilisation include the ability to more accurately identify fatigue or scheduling-related errors. In addition, giving PRED evaluation managers an education in fatigue-related human error will assist in their accurate determination and attribution of human error.

Track errors by fatigue-related indicators

Once consistent data is established, error trending should include fatigue-related queries. Human error, if properly flagged by consistent error codes, should be better segmented for reporting purposes.

Event trending should be examined by time of day, day of shift, and number of shifts on duty to assist in identifying otherwise unknown fatigue-related trends.

D. Conclusion

The project surveyed and compared responses from regulators and organisations in the nuclear, transportation, military and petroleum sectors. The responses indicated that there is no international consensus as to the "best" method for monitoring shiftwork overall in the nuclear industry, or with regards to which various aspects of a shiftwork system to monitor. Nevertheless, there were some commonalities or "best practices". There were also aspects of shiftwork that are strongly correlated with safety, and which should therefore be monitored (and regulated, as appropriate) by a regulatory organisation focused on public safety.

In the case of the AECB, this requires expanding somewhat the scope of shiftwork monitoring, and developing consistent and formalised methods based on international best practices for monitoring those components of shiftwork most related to safety. Staffing levels, overtime distribution, length of shift, timing of shift turnovers, and human performance indicators or measures should be established as safety-related features that are checked on a consistent basis.

Tracking the success of any change in shiftwork monitoring requires greater internal consistency in data reporting and tracking. Establishing a consistent set of data reporting methods and error codes will greatly contribute to the AECB's ability to trend and track fatigue-related safety issues. Additional education of AECB Project Officers, as well as licensee representatives, will assist in providing individuals at a plant level with the tools they need to properly address shiftwork-related issues.

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Appendix B: Survey

Survey of Shiftwork Monitoring in Regulatory Organizations Worldwide

Below please find a twelve question survey on how your organization monitors shiftwork practices. Please fill this out as soon as possible and return it (via email or fax) to:

Kevin Kulp Circadian Technologies 125 CambridgePark Drive Cambridge, MA 02140 USA	Email: kwk@circadian.com Fax (USA): 001-617-492-3787 Phone: 617-492-5060, ext. 615

This survey should only take a short time to complete. If you would prefer to answer the survey by phone, simply let us know. Feel free to use a separate page to answer some of the questions if you don't have enough space below. We will be pleased to provide you with a copy of the final report as a way of thanking you for taking the time to provide us with information.

1. Which industries are your regulatory organization responsible for?

    a. What type of facilities or operations are in these industries? (e.g. automatic vs. manual operations, five day vs. seven day operations)

2. Which components of shiftwork does your regulatory organization monitor? Components might include:

    a. Limits to hours of work (by day - 8 hour shifts vs 12 hour shifts, by week, by year, etc.)
    b. Shift pattern (days on/off, speed of changing between days and nights)
    c. Work organization (how or when safety-specific work is organized within a shift)
    d. Tracking and reporting hours of work
    e. Distribution (between employees) and total amount of Overtime
    f. Time or frequency of Shift Turnovers
    g. Transition between shift schedules when changing patterns
    h. Performance (Human error, number of significant events)
    i. General shiftwork related policies, practices and procedures (e.g. napping, timing of shift meetings, etc.)
    j. Shiftwork during maintenance outages; are normal guidelines suspended during maintenance outages?

3. How are shiftwork practices regulated? (e.g. standards, regulations, procedures, guides, etc.)

    a. Please list specific names or references for any regulations used to regulate shiftwork. practices.

    b. Please provide copies of these regulations if possible.

4. How are the regulated practices monitored by the regulator?

5. Which groups of employees are monitored? (e.g. operations, maintenance, security)

6. What is the monitoring frequency?

7. What objective methods are used to collect data on shiftwork? What subjective methods?

8. What research has your organization done in shift work?

9. Does your organization regulate shiftwork during maintenance outages?

10. Do individual companies, locations or work shifts have the freedom to set their own shiftwork policies (e.g. length or pattern of shift)?

11. What shift patterns, if any, are disallowed by regulators?

12. Is there anyone else within your organization who you think we should speak to for a few minutes about this issue?

Please add any additional comments or information that you wish us to know.

On behalf of the Canadian Atomic Energy Control Board and Circadian Technologies, thank you again for the time and effort you've donated to helping provide us with information.

Please list your contact information so that we may send you a copy of the final report. We expect this to be available for distribution in early September.

Name:
Title:
Company:
Address:

City:
State or Province:
Country:
Postal Code:

Telephone:
Fax:
Email:

What is your organization's role? (e.g. Federal Regulator, private company, etc.)

Thank you for participating.